ANIMAL SATURATION DIVING AT SIMULATED DEPTHS OF 50 AND 60 FEET: DESCRIPTION OF OPERATION AND ENVIRONMENT

by

Robert D. Murray, Shannon D. Stewart, Elly Heyder
and George M. Adams

NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
REPORT NUMBER 772

Bureau of Medicine and Surgery, Navy Department
Research Work Unit M4306.02-3114BEK9.01

Reviewed and Approved by:

Charles F. Gell

Charles F. Gell, M.D., D. Sc. (Med)
SCIENTIFIC DIRECTOR
NavSubMedRschLab

Approved and Released by:

R. L. Spher

R. L. Spher, CDR MC USN
OFFICER IN CHARGE
NavSubMedRschLab

SUMMARY PAGE

THE PROBLEM

To provide a viable system for evaluation of small animal exposures to saturation diving in compressed air. This system must be amenable to study by investigators who utilize various animal specimen collection techniques.

FINDINGS

Extended animal saturation diving can be carried out in a hyperbaric facility with chamber conditions adequate to sustain life for extended periods of time. Investigators were able to coordinate their efforts in such an exposure system, thus obtaining extensive data in the physiological responses to compressed air saturation diving.

APPLICATION

Data obtained from test animals in such exposure systems will add to the scientific knowledge necessary for the evaluation of compressed air as a breathing medium in human saturation diving.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Bureau of Medicine and Surgery Research Work Unit M4306.02-3114BEK9. The present report is Number One on this Work Unit. It was submitted for review on 28 August 1973, approved for publication on 5 February 1974 and designated as NAVSUBMEDRSCHLAB REPORT No. 772.

The animals in this study were maintained in accordance with the "Guide for Laboratory Animal Facilities and Care" as published by the National Academy of Sciences -- National Research Council, Public Health Service Publication No. 1024, revised July 1968.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

ABSTRACT

Two simulated saturation dives were conducted to monitor the physiological and biochemical responses of a model animal system to long term diving in compressed air. The dives were performed at 50 and 60 FSW for 60 and 36 days, respectively. Mean chamber CO_2 was 0.42% and 0.33% surface equivalent concentration for the 50- and 60-foot dives, respectively. Mean chamber O_2 was .51 ata and .58 ata for the 50 and 60 foot dives. No significant animal mortality was noted in either dive during which time over 825 male albino rats were exposed to pressure. The success of these two dives demonstrated the efficacy of long-term animal diving as a model system for investigation of the biochemical and physiological aspects of compressed air saturation diving.

ANIMAL SATURATION DIVING AT SIMULATED DEPTHS OF 50 AND 60 FEET: DESCRIPTION OF OPERATION AND ENVIRONMENT

INTRODUCTION

Saturation diving to permit effective diver performance between 30 feet and 150 feet has received relatively little attention, while systems for effective diver performance to 1000 feet have been developed. The advantages of long-term shallow saturation diving have been well established,[1] but the most suitable breathing medium for such diving has not yet been determined. Mixtures of nitrogen and oxygen have been used with success in shallow dives[2,3]. The availability and economics of compressed air as a saturation breathing medium warrants its evaluation in long-term saturation diving.

Nitrogen narcosis and oxygen toxicity are two obvious problems in the effective use of compressed air as a long-term breathing medium between 30-150 feet. Recent evidence suggests a possible adaptation to nitrogen with a lessened narcotic effect as saturation residence time increases in mixed nitrogen-oxygen dives[4]. The toxicity of 100% oxygen to some organ systems is well established but much remains to be investigated (e.g., heart, kidney, eye, etc.). Available evidence suggests an interaction between oxygen partial pressure and inert gas partial pressure in the rate of development of oxygen toxicity[5], however, additional evidence to support this suggestion must be obtained.

The first reported saturation dive breathing compressed air occurred in 1962 to a depth of 35 feet in which a 2-man team was exposed for 7 days[6]. Subsequent dives with subjects breathing compressed air from 16 feet to 42 feet for periods to 30 days have been reported in addition to one dive to 85 feet for 14 days and one dive to 98 feet for 10 days[7]. These dives affirm the feasibility for evaluation of compressed air in long-term saturation diving.

Previous animal studies[8,9,10] have been carried out primarily to evaluate morbidity and histopathology of rats using compressed air during prolonged diving. The present study was undertaken to evaluate the varied physiological and biochemical responses of a model animal system subjected to compressed air at 50 feet and 60 feet for time periods up to 60 continuous days. The response of the model system will be employed to define the limits for manned saturation diving using compressed air as a breathing medium.

MATERIALS AND METHODS

Facilities

Male albino rats (Charles River, Inc., North Wilmington, Mass.) were subjected to simulated depths of 50 (2.515 ata) and 60 (2.818 ata) FSW (feet of sea water) for periods up to 60 days in a hyperbaric chamber.

A standard double-lock U.S. Navy Recompression Chamber located in the Naval Submarine Medical Research

Laboratory (NAVSUBMEDRSCHLAB) Chamber Annex was used for both dives.* The total chamber volume at the surface is 500 cubic feet with an inner lock volume of 300 cubic feet. Compressed air was obtained using the facilities of the Submarine Escape Training Tank immediately adjacent to the NAVSUBMEDRSCHLAB Annex.

The chamber was fitted with an internal water tap, fed from a storage tank on the outside of the inner lock. A floor drain was adapted to allow draining of the inner lock at depth. The medical lock of the chamber was fitted with a specially designed two-tiered cage to allow decompression of large numbers of animals without diver accompaniment.

A small Bethlehem hyperbaric chamber (Model 615 HP; The Bethlehem Corporation; Bethlehem, Pennsylvania) was also utilized. This small chamber could be moved from the inside to the outside of the recompression chamber and fitted with an external air source for independent operation. The small chamber was fitted with electrical penetrations to permit monitoring of physiological changes in the animals while under pressure.

Cage Organization

Thirty "housing" cages (26 x 10 x 7 inches) (Acme Metal Products, Chicago, Illinois) were placed within the inner lock in six stacks. Cage stacks were situated three on a side within the inner lock on steel benches lining the chamber walls (Fig. 1). All cages were identified by numbered cards (1-30) with the investigators' names. Each cage was separated from it's respective litter pan by plexiglass strips placed at each end. Cages containing six animals or less were equipped with one food hopper and one water bottle. Additional food hoppers and water bottles were added to cages with more than six animals or to cages with individual compartments designed for rapid identification and animal separation.

A system of cage rotation was employed to minimize the effect of possible "gas pocketing". Carbon dioxide, being more dense than air, could settle to the lower parts of the chamber, thereby subjecting the animals in the lower cages to a different breathing medium than those in the upper cages. These sustained differences in breathing media from one cage to the next could effect differences in experimental results. Cage rotation was accomplished during cage maintenance periods.

Chamber Operation

All personnel responsible for operating and tending the chamber were trained in their duties by the Hyperbaric Chamber Supervisor of NAVSUBMEDRSCHLAB. Laboratory personnel manned the chamber twenty-four hours a day during the entire period of each dive. Chamber operators during the periods of personnel entry were qualified divers (graduates of appropriate courses at the Naval School of Diving and Salvage).

All instruments used to monitor the internal chamber environment were

The term "dive" when used to refer to the subject of the present report will mean simulated dive in a compressed air medium.

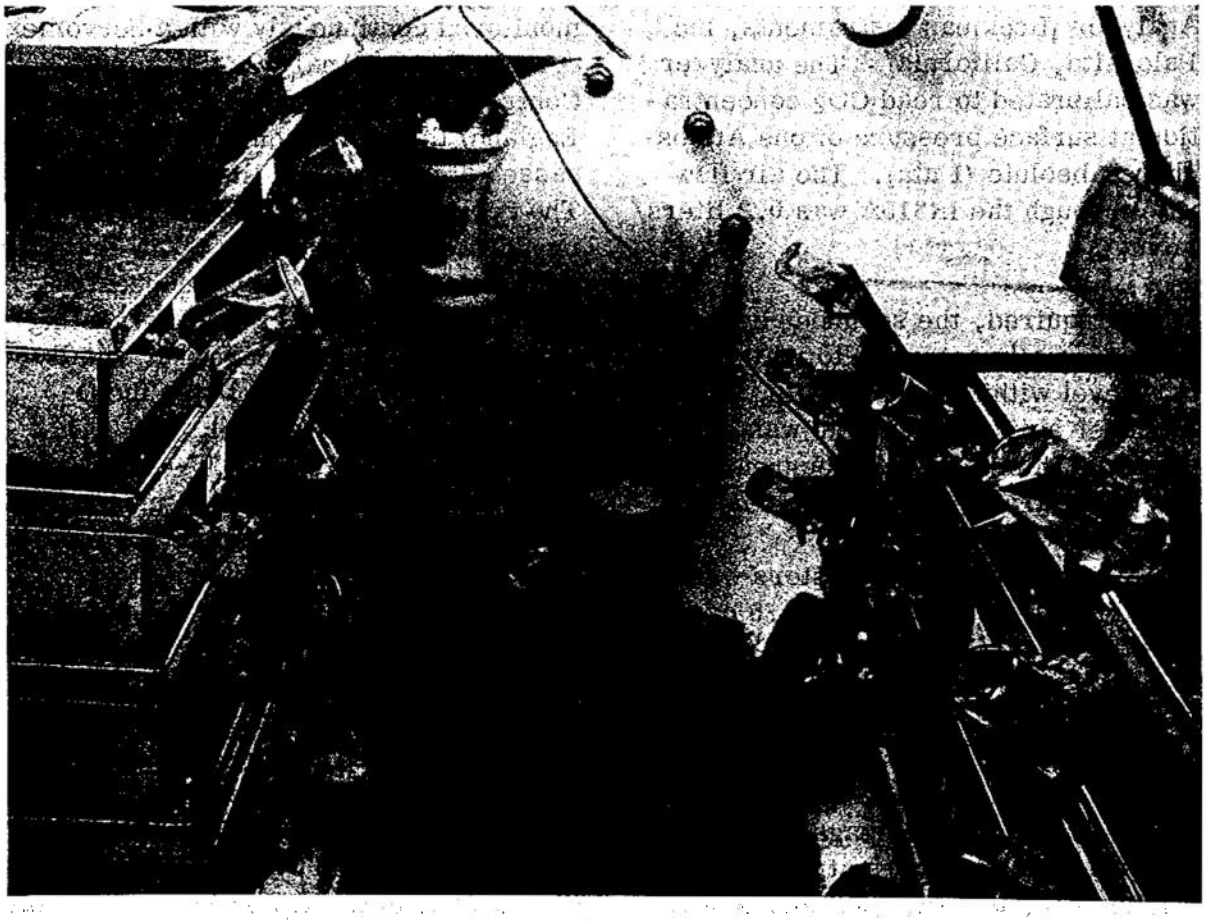

Fig. 1. Organization within hyperbaric chamber as viewed from port in outer lock. CO_2 scrubber system can be seen below the medical lock at the rear of the chamber. Silica gel canisters are on side of deck plate below cages. See text.

calibrated twice daily. Values for chamber O_2, CO_2, temperature and relative humidity were determined periodically and the data recorded. In addition to the atmospheric readings all personnel entries and other information relevant to the dive were recorded.

Chamber watches were organized into three 8-hour shifts. A "casualty bill" outlining contingency action in the event of eight possible chamber problems was read prior to assuming each watch.

Internal Environment

Chamber carbon dioxide (CO_2) levels were maintained below 0.5% Surface Equivalent Concentration* primarily through the use of a CO_2 scrubber system consisting of lithium hydroxide absorbent canisters. The lithium hydroxide canisters were inserted into a U. S. Navy CO_2 Canister Receptacle Size 60 CFM (Desomatic Products, Inc., Falls Church, Virginia) located within the inner lock.

Chamber CO_2 was monitored continuously with a Beckman IR315A CO_2

**SURFACE EQUIVALENT CONCENTRATION = Concentration in air at 1 Atmosphere Absolute (ata) x ata of pressure.*

Analyzer (Beckman Instruments, Inc., Palo Alto, California). The analyzer was calibrated to read CO_2 concentration at surface pressure of one Atmosphere Absolute (1 ata). The air flow rate through the IR315A was 0.2 liters/minute.

As required, the scrubber system was externally activated to maintain the CO_2 level within preset limits. The scrubber activation system was designed to minimize the occurrence of electrical arcing within the chamber.

Lithium hydroxide canisters were depleted at an average rate of 1.5 canisters per day. Canisters were replaced by divers inside the chamber during specimen collection or cage maintenance periods. Lithium hydroxide canisters would be prepared at the surface, placed in polyethylene bags and compressed with the divers at the time of chamber entry. This procedure was designed to prevent aerosolization of the canister contents which cause irritation through drying of mucosal membranes.

Chamber "venting", the introduction of fresh air into the chamber while maintaining test depth, was another means of controlling CO_2 levels. Venting was the method of choice for atmospheric control during personnel entries or when oxygen, relative humidity or internal temperature changes required renewal of the chamber atmosphere.

Because the chamber environment was compressed air, the maximum chamber oxygen (O_2) concentration was 20.9% of chamber air. The minimum allowable O_2 concentration was 19.0% of chamber air. Oxygen concentration was monitored continuously with a Servomex OA 120 Oxygen Analyzer (Servomex Controls Ltd.; Crouborough Sussex, England) through which chamber air was passed at a rate of 10 liters/minute. The Servomex readings were direct measurements of percent O_2 in chamber air. A fall in chamber O_2 concentration to 19.0% was corrected by venting the chamber, a procedure that usually required ten minutes to bring the O_2 back up to the 20.9% level.

Internal temperature was monitored in degrees Fahrenheit with a YSI Model 44TD battery-powered thermistor recorder equipped with a YSI Number 44004 Precision Thermistor (Yellow Springs Instrument Co., Inc., Yellow Springs, Ohio). The maximum allowable temperature for the chamber was 87° and the minimum was 72°. Minimum chamber temperature was incidentally controlled by scrubber heat production, internal lighting and animal metabolism. Maximum chamber temperature was controlled by venting the chamber.

Relative humidity for the dives was taken to be either the reading on an Abbeon Certified Hygrometer (Abbeon Cal, Inc., Santa Barbara, California) attached internally to a chamber view port or a value calculated from a wet bulb (with a thermister dry bulb reading) suspended within the chamber. The latter method of relative humidity determination could only be used during periods of personnel entry into the chamber.

Control of relative humidity was accomplished directly through the use of an absorbent granular litter as a cage pan base and by silica gel canisters

which were regenerated by oven drying and placed in the chamber on a rotating basis. Relative humidity was indirectly controlled by the CO_2 scrubber system and by venting.

Determination of internal relative humidity during the two dives was of questionable value since it is not known whether relative humidity meters give accurate readings while under pressure[11].

Ammonia gas was controlled by venting the chamber and sprinkling boric acid powder over the absorbent litter in the cage pans.

Diving Procedures

On any given day there were one to three personnel entries to accomplish animal specimen collection, cage maintenance and animal replacement. Investigator specimen collection schedules were coordinated to uniformly distribute the diving workload and maximally utilize available cage space. For those days on which diver workload was maximal, the most experienced divers were employed to ensure task completion.

Specimen collection was performed during the morning dives at 8:30 and 10:00 a.m. If one sampling period was required, it was normally performed at 8:30 a.m. Daily cage maintenance was performed in the afternoon at 2:00 p.m. on most days. On weekends and holidays, the individual divers were allowed to perform cage maintenance as it best suited their schedules.

The average compression rate was 57 ft./min. with a rate of 29 ft./min. when animals were to be brought into the chamber. The average decompression rate was 50 ft./min. with a rate of 8 ft./min. when blood samples were being decompressed with the diving personnel.

In a 50-foot dive in compressed air, the maximum no-stop decompression bottom time allowed by Navy Diving Tables[13] is 100 minutes. A "safe time" of 80 minutes with a 90-minute maximum bottom time was instituted and strictly observed. At a 60-foot test depth the no-stop decompression bottom time is 60 minutes. Accordingly, a 50-minute "safe time" with a 55-minute maximum bottom time was observed. At no time during either dive was a decompression stop required for the surfacing of diving personnel.

All personnel entering the chamber were qualified as divers in accordance with existing Naval Diving and Medical Department requirements[12,13]. Hospital Corpsmen of limited hyperbaric experience attended a special course in Hyperbaric Nursing given by the Naval Undersea Medical Institute before participating in the dives. Prior to each personnel entry into the chamber, the chamber operator ascertained the person's status through verbal discussion and reference to the dive log. A Diving Medical Officer was always on call to aid in any medical problems experienced by the divers.

Animal Decompression Schedules

For the termination of the 50 and 60 foot dives, the general method of halving the depth and performing decompression stops from 15-30 minutes was

employed. These schedules are seen in the dive profiles in Figures 2 and 3, and in Tables 1 and 2.

The criteria used for determining animal decompression sickness were: lethargy, limb twitching, respiratory distress, and comatose conditions[14].

Animal Care

During the dives, animals were closely observed by divers to ascertain their state of health. The divers included Navy Hospital Corpsmen and an Air Force animal technician assigned to the Animal Sciences Branch of NAVSUBMEDRSCHLAB. These trained personnel, as well as the other divers, observed the animals while at depth and ascertained their health status by looking for signs of illness manifested in coat texture, breathing patterns and composition of fecal matter. An Air Force Veterinary Officer assigned to NAVSUBMEDRSCHLAB was available at all times for counseling regarding problems encountered in the planning and performance of the dives and for examination of the animals in the chamber. A trained animal caretaker provided assistance in cage washing and food and litter procurement.

Cage maintenance was performed every day on either the even or the odd-numbered cages, thus ensuring a complete maintenance of all cages at least every two days. Each day food and water rations were supplied to all cages as conditions warranted. Water bottles were replaced as conditions warranted or once a week. Complete removal of all unused food from the hoppers and resupplying with fresh food was accomplished every three days. This precaution was taken to prevent the growth of mold which could have interfered with animal eating habits or affected their general well-being[10].

For cage maintenance procedures, two divers were compressed to test depth with litter, food, boric acid, clean cage pans, and clean water bottles. Cages were rotated in a counterclockwise direction and from top to bottom. Clean pans were filled with litter and covered with boric acid powder. Plexiglass strips were placed in the pan and the cage placed on top as rotation continued. Used cage pans were decompressed with the divers and thoroughly cleaned and washed for use at a later time (Fig. 4).

After cage maintenance had been accomplished, the inside of the inner lock was cleaned of spilled food and litter and sponged down to improve the overall condition and sanitation of the inner lock.

To ensure the regularity of the animal environment, lights were turned on every morning at 6:00 a.m. and turned off at 6:00 p.m. Chamber tenders made observations through viewports during "lights on" periods to determine the status of food and water rations in particular and inner lock conditions in general.

Experimentation

No results of specific investigator experimentation will be presented in this paper except as they refer to the general operation of the dive and control of the chamber environment. However

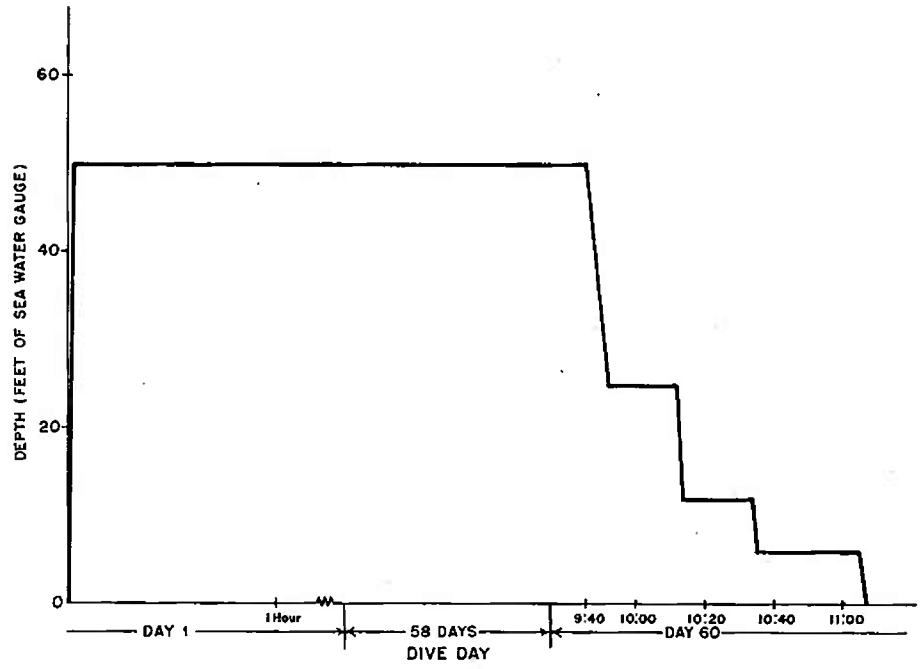

Fig. 2. Dive profile for 50 foot/60 day animal saturation dive.

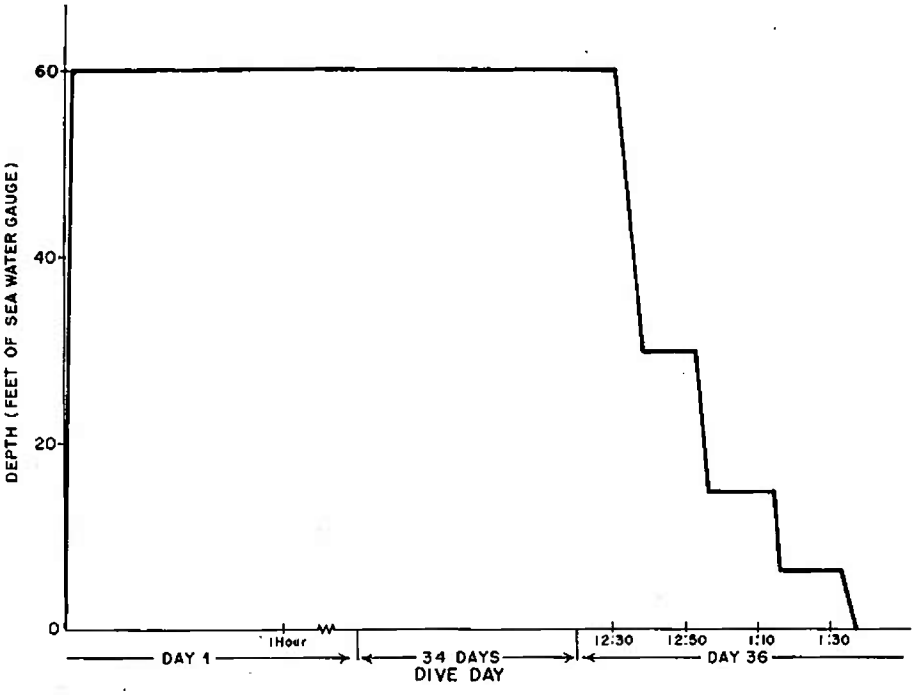

Fig. 3. Dive profile for 60 foot/36 day animal saturation dive.

Table 1. Decompression Schedule Used to Terminate 50 Foot/60 Day Saturation Dive on Compressed Air

Depth In FSWG	Rate Of Decompression	Time For Procedure	Total Time At End Of Procedure
from 50 to 25	4 ft./min.	6 min. 15 sec.	6 min. 15 sec.
at 25	0 ft./min.	20 min.	26 min. 15 sec.
from 15 to 12	6 ft./min.	2 min. 10 sec.	28 min. 25 sec.
at 12	0 ft./min.	20 min.	48 min. 25 sec.
from 12 to 6	3.8 ft./min.	1 min. 35 sec.	50 min.
at 6	0 ft./min.	30 min.	80 min.
from 6 to 0	3.8 ft./min.	1 min. 35 sec.	81 min. 35 sec.

Table 2. Decompression Schedule Used to Terminate 60 Foot/36 Day Saturation Dive on Compressed Air

Depth Of FSWG	Rate Of Decompression	Time For Procedure	Total Time Of The Procedure
from 60 to 30	4.0 ft./min.	7 min. 30 sec.	7 min. 30 sec.
at 30	0 ft./min.	15 min.	22 min. 30 sec.
from 30 to 15	4.0 ft./min.	3 min. 45 sec.	26 min. 15 sec.
at 15	0 ft./min.	18 min.	44 min. 15 sec.
from 15 to 6.5	4.5 ft./min.	1 min. 51 sec.	46 min. 6 sec.
at 6.5	0 ft./min.	20 min.	66 min. 6 sec.
from 6.5 to 0	3.7 ft./min.	1 min. 45 sec.	67 min. 51 sec.

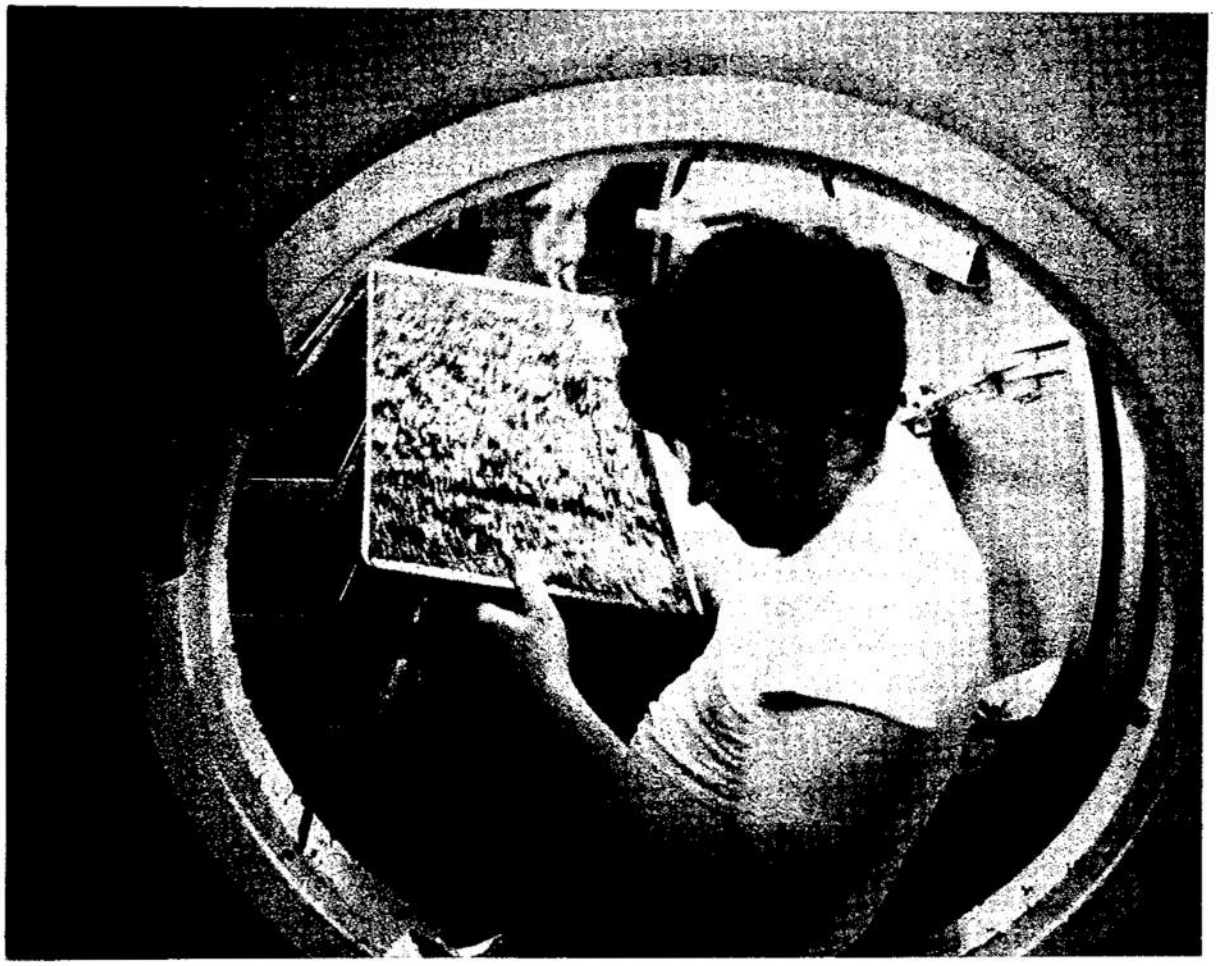

Fig. 4. Diver removes dirty cage pan from inner lock during cage maintenance procedures at test depth. See text.

the type of experiments which were carried out to determine the biological effects of shallow air saturation diving included:

1) thyroid function
2) microbial and pulmonary clearance and pulmonary histopathology
3) osmotic fragility
4) blood gas analysis
5) mineral metabolism
6) LDH, lactate and pyruvate metabolism
7) dental analysis
8) acid base balance
9) plasma and red cell electrolyte analysis

10) urea, ammonia, total nitrogen and amino acid assays

11) visual evoked cortical potentials

12) EEGs recorded from implanted electrodes

13) serum and urine electrolyte analysis in small rats

14) metabolic stress evaluation

15) brain, heart, liver, kidney and lung pathology

Specimen collection was performed by divers on a regular basis according to the schedule of the individual investigators. Animal specimen collection consisted of five distinct experimental procedures:

(1) blood collection at depth with subsequent decompression of whole blood and carcasses;

(2) urethral ligation at depth with subsequent safe animal decompression;

(3) safe decompression of intact animals;

(4) transfer of animals from the inner lock to the surface while maintaining them at test depth through the use of the Bethlehem chamber; and

(5) excursion diving of animals using the Bethlehem chamber.

Blood was collected at test depth from animals anesthetized with sodium pentobarbital (0.1 gram/100 grams) injected intraperitoneally. Blood remained in capped syringes or was transferred to test tubes and decompressed with the divers at a rate of 8 ft./min. Dive protocol specified that the responsible investigator or his representative be present for acceptance of the specimen immediately upon its arrival at the surface.

On days that urethral ligation was accomplished, the divers would ligate and transfer the animals to a small "holding" cage (16 x 9 1/2 x 7 inches) (Acme Metal Products, Chicago, Illinois). That afternoon the cage maintenance divers would place the holding cage into the medical lock for decompression according to the schedule of the individual investigator.

For direct safe decompression, intact animals were transferred from their housing cages to the cylindrical cage within the medical lock. The medical lock was then decompressed by the individual investigator according to his own schedule.

When specific physiological activities were monitored outside of the recompression chamber, the Bethlehem chamber was used to maintain test depth during transfer of selected animals from the inner lock to the outside (surface). Once at the surface, the small pressurized chamber was connected to an external source of compressed air for maintenance of the breathing atmosphere. This transfer was used for purposes of electrical monitoring of brain functions in rats with implanted electrodes. Prior to surface transfer, all electrode leads were connected to the implants by the divers within the chamber. When the experimentation was

completed the small chamber was returned to the inner lock and the animals returned to their housing cages.

The Bethlehem chamber was also used for excursion diving of animals from test depth. Selected animals would be placed in the small chamber and kept at test depth while being transferred via the outer lock to the surface. Once at the surface, the responsible investigator would excurse the animals by altering the pressure within the small chamber. Upon completion of these procedures, the animals were returned to the recompression chamber for specimen collection.

RESULTS AND DISCUSSION

The 50 foot dive was accomplished with no major deviation from the dive plan. The 60 foot dive was planned to last for 60 days, however contamination of the air supply resulted in securing of the volume tanks. With no alternative compatible air supply immediately available, the 60 foot dive had to be terminated on the thirty-sixth day. Since the termination of the 60 foot dive, the recompression chamber has been relocated to the chamber room of the NAVSUBMEDRSCHLAB complex where it will be utilized in conjunction with existing compressor systems and volume tanks.

Atmospheric monitoring was accomplished hourly in the 60 foot/36 day dive. Values for the 50 foot/60 day dive were recorded less regularly but at least every four hours. Means and standard errors for the 60-foot dive are based on the hourly recorded values. Means and standard errors for the 50 foot dive are calculated from all entries in view of the lesser number of recordings.

Figures 5 and 6 show the surface equivalent CO_2 concentration with the standard error of the mean for the 50 and 60 foot dives, respectively. The mean surface equivalent concentration for the 50 foot dive was 0.42%. It was determined by the investigators after the 50 foot dive that CO_2 in the second dive should be maintained between 0.3% and 0.4%. This was accomplished by decreasing the maximum allowable CO_2 level through more frequent scrubbing. The mean surface equivalent CO_2 concentration for the 60 foot dive was 0.33%. The relatively large standard errors of the mean in the CO_2 concentrations during both dives reflect the cylical regulation of this parameter, i.e., adjustment from a maximum to a minimum level by scrubbing or venting as conditions indicated.

Although CO_2 was held between 0.3 and 0.5% in the dives, a lower range can be attained with more frequent venting and scrubbing. Frequent venting was not utilized because of the demand that it placed on the storage facilities of the Escape Training Tank. Frequent scrubbing has the disadvantage of increasing internal temperature through scrubber heat production as well as increasing dive cost through increased canister utilization.

Another problem which must be considered in frequent venting and scrubbing operations is the noise created by both of these processes. Noise within hyperbaric chambers has long been of concern to the Navy[11,15] and the effect

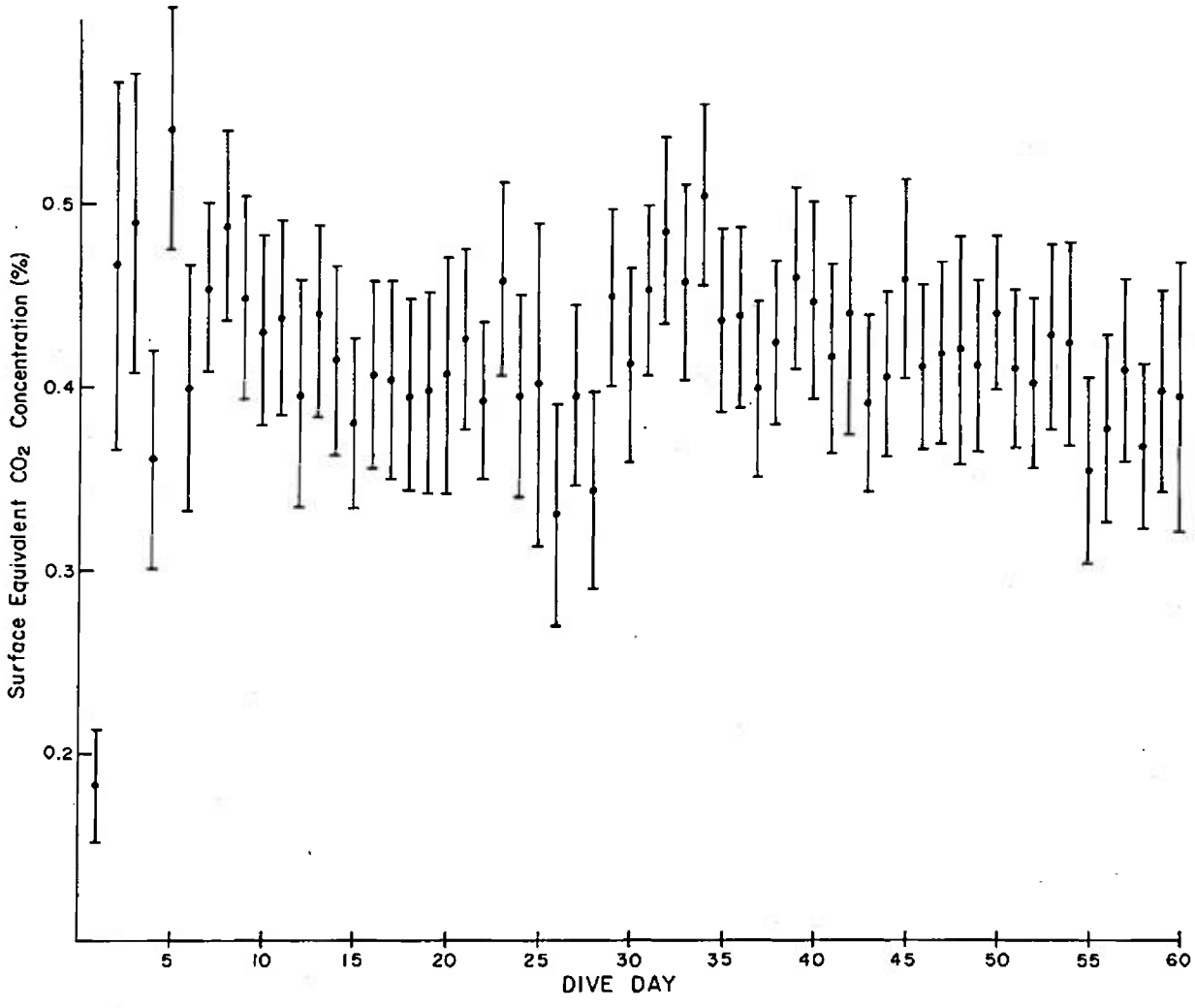

Fig. 5. Mean surface equivalent carbon dioxide concentration ±SEM for 50 foot/60 day animal saturation dive.

of noise on various physiological functions of small animals has been documented[16,17]. Thus, the problem is to reduce the CO_2 concentration as low as possible without increasing the temperature, cost, and noise parameters of the dives.

Since the termination of the 60 foot dive, a flow-through life support system has been developed for the recompression chamber. This system will substantially reduce the noise and heat within the chamber while maintaining CO_2 at a low level. The CO_2 absorbent used in this system is in granular form and is cheaper than canister lithium hydroxide. Additionally this system avoids taxing the air supply systems by frequent venting.

Figures 7 and 8 represent the surface equivalent O_2 concentration with the standard error of the mean for the 50 and the 60 foot dives, respectively. The mean for the 50 foot dive was 51.1% versus 57.8% for the 60 foot dive. These values primarily reflect the

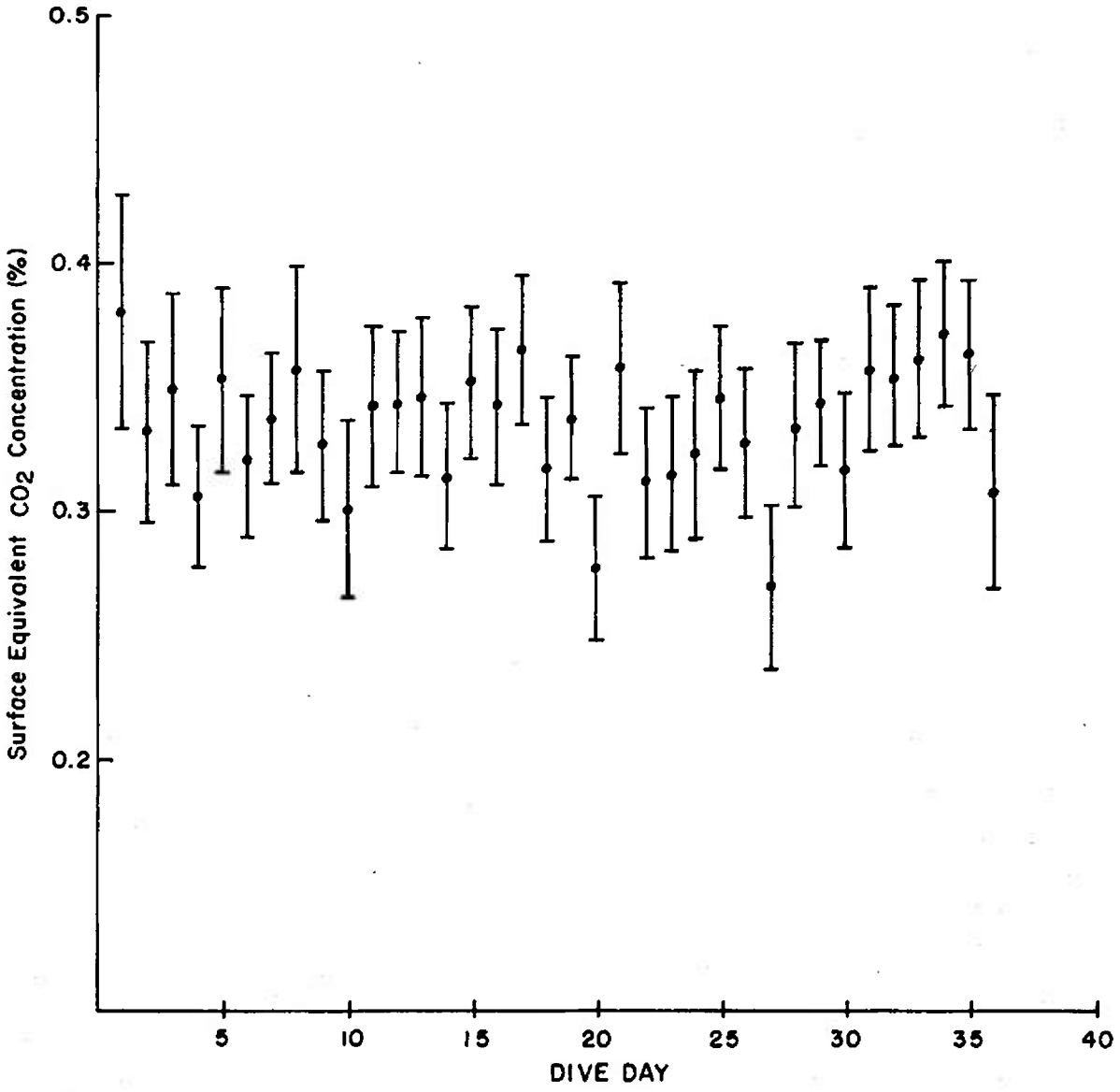

Fig. 6. Mean surface equivalent carbon dioxide concentration ±SEM for 60 foot/36 day animal saturation dive.

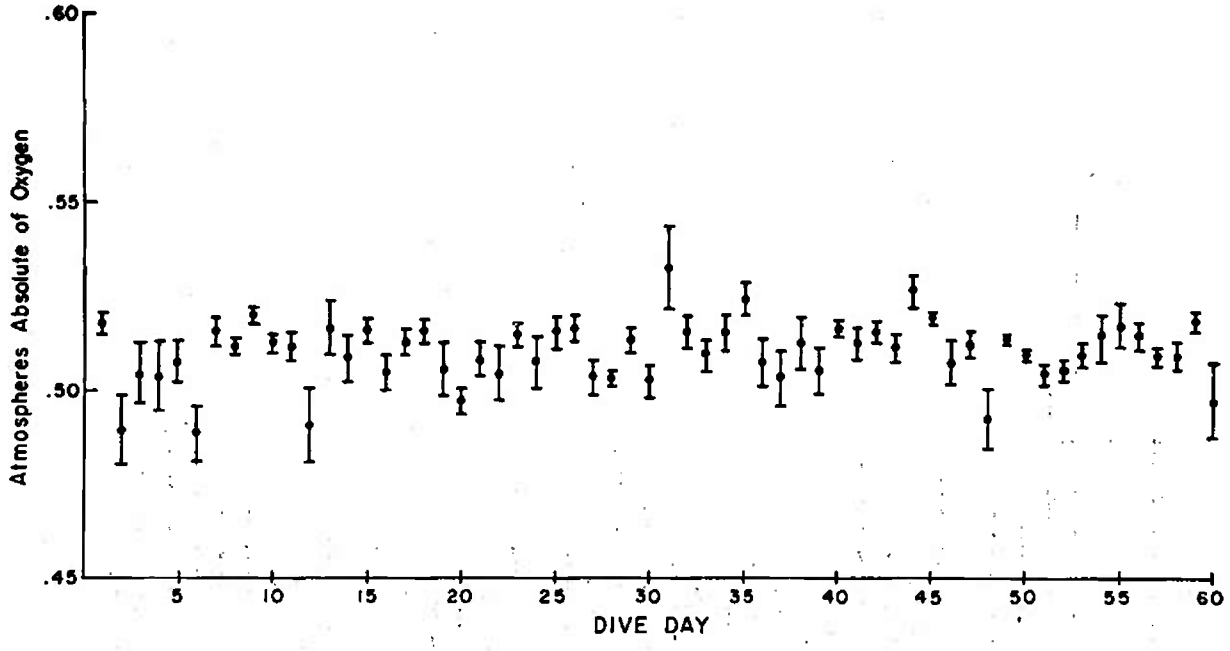

Fig. 7. Mean atmospheres absolute oxygen concentration ±SEM for 50 foot/60 day animal saturation dive.

difference in depth, 2.515 ata for 50 feet and 2.818 ata for 60 feet.

The mean internal chamber temperature was 78.8°F for the 50-foot dive and 82.6°F for the 60-foot dive. Regulation of chamber temperature presented a problem only at its maximal limit. Minimum chamber temperature was always achieved through animal metabolism and scrubber and lighting heat production.

The control of maximum chamber temperature became a problem when activation of the CO_2 scrubber system brought temperatures up to 87°F. Scrubber heat production increased as a temperature factor when the lithium hydroxide canisters became saturated with water vapor and CO_2. Saturation caused the canisters to work less efficiently and the scrubber had to be operated for longer periods of time to reduce CO_2 levels. This longer activation made a significant contribution to chamber temperature. Elimination of scrubber heat production can be accomplished through the flow-through life support system presently installed in the chamber.

Heat generation by the lighting system will be controlled through the use of acrylic plastic "light pipes" (J. M. Canty Associates, Tonawanda, New York). These light pipes are regulated by an externally located rheostat for control of current load and, therefore, heat production.

Relative humidity was consistently measured only toward the end of the 50-foot dive when the hygrometer was

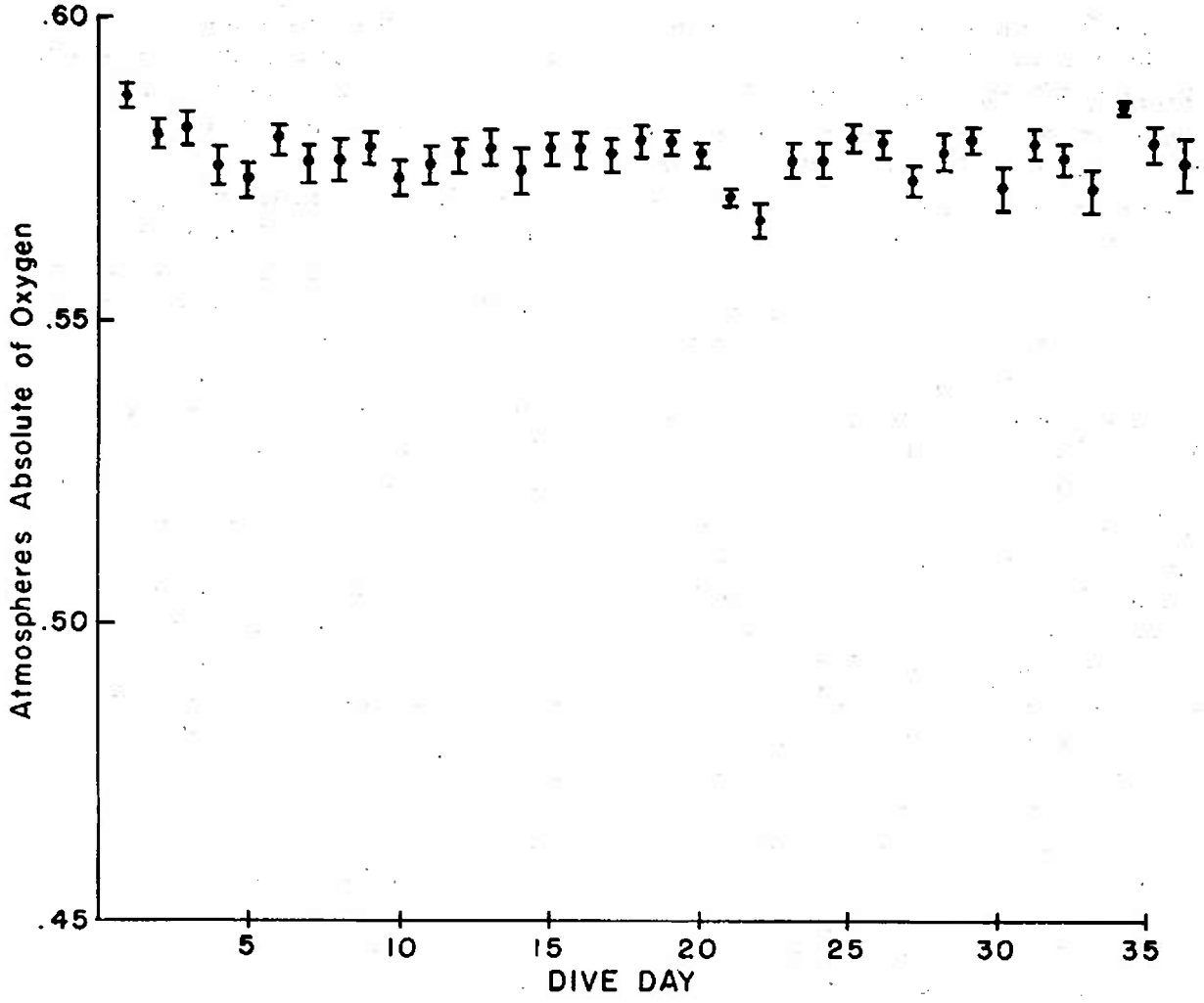

Fig. 8. Mean atmospheres absolute oxygen concentration ±SEM for 60 foot/36 day animal saturation dive.

installed in one of the chamber viewports. For the final 17 days of that dive mean relative humidity was 69.5%. During the 60-foot dive mean relative humidity was 74.9%.

One source of excess water vapor was leaking from water bottles. Minor deviation from test depth during venting often caused leaking of water bottles due to pressure differences across the nipple. Leakage may be controlled by an automatic pressurized tubular watering system.

During the 50-foot dive, radioisotopes were used within the chamber by one of the investigators. Isotopes were used only by personnel working in conjunction with AEC licensed investigators (AEC License #06-01765-03 (J-73)). Weekly radiation screening was performed to determine the level of contamination of the chamber. "Swipes" were made at

ten sites within the chamber and monitored by Nuclear Medicine Technic Training Division personnel of the Naval Undersea Medical Institute. At no time was the swipe count significantly higher than normal background levels in counts per minute.

Air samples were taken during the 50 foot dive to determine contamination in the chamber atmosphere. These samples were collected into evacuated bottles through penetrations in the chamber wall. The samples were sent to the Naval Air Rework Facility at Quonset Point, Rhode Island, for analysis and results were returned to the Hyperbaric Chamber Supervisor, NAVSUBMEDRSCHLAB. All the samples taken during the dive were found to conform to Federal Specifications for hyperbaric environments (Federal Specification BB-A-1034A; Air, Compressed, for Breathing Purposes; December 15, 1970).

There was no incidence of animal decompression sickness due to surfacing from either the 50- or the 60-foot test depth. Decompression was performed on either selected animals in the medical lock or on the entire population of the inner lock at the termination of the respective dives. Decompression schedules employed have been described above.

During compression to test depth a reaction was noted in the animal population. From the viewport animals were observed to become hyperactive and run from end to end within their cages. Soon after reaching test depth this hyperactivity subsided and the animals appeared to return to normal activity. It is not known whether hyperactivity resulted from compression stress or increased sound levels reached within the recompression chamber.

In preliminary studies no gross histopathological changes have been noted in lung sections from animals exposed to the 50 and 60 foot test depths for varying lengths of time. Lung tissue from five rats exposed for 7 days near the termination time of the 60 foot dive were thoroughly examined and showed no deleterious effects of the contaminated air supply from the Training Tank.

Of the 406 rats exposed to the 50 foot test depth, 7 or 1.8% died while at depth. All seven of these rats were young (70 grams or less) and had arrived from the breeder on the morning the dive started. Six of the animals were on a special low calcium diet. The resident veterinarian determined that death had resulted from the compounded stresses of immaturity, shipment exposure, diet and depth. Because of the death of these animals, an acclimatization period of at least one week was initiated between the arrival of animal shipments and the entry of those animals into the chamber.

Of the 450 rats exposed to the 60 foot test depth, 3 or 0.7% died while at depth. Because of cannibalization, autopsy was difficult but one partially intact carcass showed signs of a gastrointestinal infection.

One hundred and one human dives were performed during the 50 foot saturation dive for purposes of animal care and specimen collection. A total diver time of 8,063 minutes was spent in these operations including 7,583

minutes in task completion and 480 minutes in decompression.

In the shorter 60-foot saturation dive, 67 human dives were performed occupying a total diver time of 5,095 minutes. Of this diver time, 4,677 minutes were spent in operations and 418 minutes in decompression. Total bottom time for the 50 foot dive was 94.0% of the total dive time as compared to 91.8% for the 60 foot saturation dive. These figures partially reflect the shorter period available for task completion at test depth in the deeper dive.

Approximately forty persons were involved in diving and chamber operation during the course of the two dives. In the combined dives, over 219 man hours were spent in diving in conjunction with more than 2,300 man hours spent in chamber tending and operation.

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UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE MEDICAL CENTER

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
ANIMAL SATURATION DIVING AT SIMULATED DEPTHS OF 50 AND 60 FEET: DESCRIPTION OF OPERATION AND ENVIRONMENT

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Interim report

5. AUTHOR(S) *(First name, middle initial, last name)*
Robert D. Murray, Shannon D. Stewart, Elly Heyder and George M. Adams

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
5 February 1974	18	17

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. M4306.02-3114BEK9.01	NSMRL Report No. 772
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Submarine Medical Rsch Lab Box 900, Naval Submarine Base Groton, Connecticut 06340

13. ABSTRACT

Two simulated saturation dives were conducted to monitor the physiological and biochemical responses of a model animal system to long-term diving in compressed air. The dives were performed at 50 and 60 FSW for 60 and 36 days, respectively. Mean chamber CO_2 was 0.42% and 0.33% surface equivalent concentration for the 50-and 60-foot dives, respectively. Mean chamber O_2 was .51 ata and .58 ata for the 50- and 60-foot dives. No significant animal mortality was noted in either dive during which time over 825 male albino rats were exposed to pressure. The success of these two dives demonstrated the efficacy of long-term animal diving as a model system for investigation of the biochemical and physiological aspects of compressed air saturation diving.

DD FORM 1 NOV 65 1473 (PAGE 1)
S/N 0102-014-6600

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Saturation Diving						
Environmental Control						
Compressed Air						
Hyperbaric Environment						